THE BIGGEST CARBON 14 DATING MISTAKE EVER

by Daniel R. Porter

> "*There is a lot of other evidence that suggests to many that the shroud is older than the radiocarbon dates allow, and so further research is certainly needed. Only by doing this will people be able to arrive at a coherent history of the shroud which takes into account and explains all of the available scientific and historical information*" —**Christopher Ramsey**, head of the Oxford Radiocarbon Accelerator Unit which participated in the 1988 Carbon 14 Dating of the Shroud. (March 2008)

> "*[T]he age-dating process [in 1988] failed to recognize one of the first rules of analytical chemistry that any sample taken for characterization of an area or population must necessarily be representative of the whole. The part must be representative of the whole. Our analyses of the three thread samples taken from the Raes and C-14 sampling corner showed that this was not the case.*" —**Robert Villarreal**, Los Alamos National Laboratory (LANL) chemist who headed a team of nine scientists at LANL who examined material from the carbon 14 sampling region. (August 2008)

It may well go down as the biggest radiocarbon dating mistake in history; not because there is anything wrong with the measurement process (there may not have been); not because there is anything inherently wrong with carbon 14 dating (there is not); not because of shoddy sample taking (which indeed was shoddy); not because of red flags that should have raised serious questions (there were quite a few); and not even because a basic tenet of archaeological dating was ignored by good scientists.

No, the reason is because, now, nearly two decades later, whenever carbon 14 dating is discussed in high school or college classrooms, students are likely to raise a hand and ask some probing questions: What about the Shroud of Turin? Was it dated correctly? If not, how could so many scientists from so many reputable radiocarbon dating laboratories screw up so badly?

Were mistakes made in the radiocarbon dating of the shroud? Were enough serious mistakes made to call the results into question? Consider what no less than twenty-one scientists from the University of Oxford, the University of Arizona, the Institut für Mittelenergiephysik in Zurich, Columbia University, and the British Museum wrote in a

peer-reviewed paper published in 1989 in *Nature*, the prestigious international weekly journal of science:

> The results of radiocarbon measurements at Arizona, Oxford and Zurich yield a calibrated calendar age range with at least 95% confidence for the linen of the Shroud of Turin of AD 1260 - 1390 (rounded down/up to nearest 10 yr). These results therefore provide conclusive evidence that the linen of the Shroud of Turin is mediaeval.

How can anyone argue with this? The radiocarbon measurements were done, not at one laboratory, but at three highly regarded institutions. The authors are emphatic. The results provide not just evidence but *conclusive* evidence. Does this not suffice to answer the students' questions?

No, not if we wonder what prompted the questions. The Shroud of Turin is a religious relic. Many people believe it was the burial cloth of Jesus of Nazareth and history. Were the questions prompted by religious beliefs that run contrary to science? Or is there new information that suggests that, indeed, mistakes were made?

THE WELL INFORMED STUDENT

It might be tempting to say that the subject is about a religious relic and thus discussion is inappropriate for the science classroom of a secular institution. But that is the wrong answer. This is a religious relic, but it is also an archeological artifact, one that has been rigorously studied scientifically. This happened in 1978 when several scientists examined it in Turin. This happened when the radiocarbon tests were conducted in 1988. This happened, also, when in 2004, a U.S. government publication revisited the tests. And in 2005, another secular, peer-reviewed scientific journal, *Thermochimica Acta,* published a paper that severely challenged the results of the 1988 radiocarbon dating. It didn't stop there. Los Alamos National Laboratory chemist, Robert Villarreal recently reported that a nine member team of scientists chemically characterized threads from the carbon dating region of the cloth with some of the most advanced equipment available in that lab. And in August of 2008, the science journal, *Chemistry Today*, published a twelve page article on the shroud's carbon dating. It is the wrong answer simply because the matter of the radiocarbon dating has nothing to do with religion.

It is the wrong answer because it denies the student a chance to look at the methods, procedures and data, and to learn from the experience. Here is a chance to understand what can go wrong in radiocarbon dating and other scientific endeavors (if indeed anything did go wrong). Here is a chance to see how scientific conclusions are continuously being

challenged by new information. And here is a stimulating case study for students to learn about radiocarbon dating.

Yet, as much as we might wish to avoid it in the science classroom, the shroud is nonetheless enmeshed with religiosity. As Philip Ball, who for many years was the physical science editor of *Nature*, wrote in a commentary in *Nature's* online edition following the *Thermochimica Acta* paper:

> The scientific study of the Turin shroud is like a microcosm of the scientific search for God: it does more to inflame any debate than settle it. . . And yet, the shroud is a remarkable artifact, one of the few religious relics to have a justifiably mythical status. It is simply not known how the ghostly image of a serene, bearded man was made. It does not seem to have been painted, at least with any known pigments.

The point about the ghostly image is poignant. If we limit ourselves to quality science, and in particular peer-reviewed science, we find that what Ball writes is true: nobody does know how the image was formed. But what if anything does the image have to do with the radiocarbon dating? Simply this: Were it not for the intriguing mystery of the image, possible radiocarbon dating mistakes might never have been discovered. (1)

It is not wrong for science to test and challenge religious beliefs; for instance the creation of the universe or the evolution of the human species. And similarly, it is not wrong for scientists to challenge the authenticity of the shroud. Indeed, such examination should be welcomed by all. But when science does so, care is in order. Any results, whatever they might be, will face extraordinary scrutiny.

The radiocarbon dating results did stimulate debate. The first responses from shroud apologists were a series of poorly developed and scientifically questionable hypotheses. For instance, some suggested that a fire in 1532, which nearly destroyed the shroud, somehow changed that ratio of carbon 14 to carbon 12 and carbon 13 isotopes in the cloth. Others suggested that a biological polymer had grown on the fibers of the cloth and that this newer material skewed the results. But these ideas, when understood, did not gain much support among scientists. (2)

But Ball, in his commentary, explained two distinctly different scientific empirical findings that challenged the accuracy of radiocarbon dating results. These findings, by chemist Raymond Rogers, clearly demonstrated that the area of the cloth from which the samples were taken was chemically unlike the rest of the cloth in several ways. Thus he concluded

that the samples were not representative of the cloth. Moreover, one of those chemical differences, the amount of vanillin, provided a new clue about the cloth's age. Samples from the main part of the cloth, unlike the carbon 14 sample area, did not contain any vanillin. If the shroud was only as old as the radiocarbon date, it would have plentiful vanillin.

Who was this Rogers, who would dare challenge the auspicious conclusions of many of his peers in three of the worlds leading radiocarbon laboratories? He was eminently qualified. For many years, before retiring, Rogers was a highly regarded chemist at the Los Alamos National Laboratory. He had been honored as a Fellow of this prestigious UCLA laboratory. In his home state of New Mexico, he was a charter member of the Coalition for Excellence in Science Education. For several years he served on the Department of the Air Force Scientific Advisory Board. He had published over fifty peer-reviewed scientific papers in science journals. He was one of many scientists selected to study the shroud in 1978. Wrote Ball, "He has a history of respectable work on the shroud dating back to 1978, when he became director of chemical research for the international Shroud of Turin Research Project."

It should also be noted, as Ball makes clear, that Rogers had not set out to prove that radiocarbon dating was wrong. He had complete respect for the technology and the quality of work done by the labs. He had already rejected the two media-popularized theories as to why the tests might be invalid (the scorching fire and the biological film). Rogers had a disdain for pseudo-science, for those who ignored scientific methods and for those who questioned unquestionable scientific observations. Rogers called those who persisted in defending and promoting unscientific theories, the "lunatic fringe" of shroud research.

INVISIBLE REWEAVING?

There was another hypothesis floating about to explain why the carbon 14 testing might be wrong. It was gaining traction among some shroud researchers and on the internet. Two shroud researchers, M. Sue Benford and Joe Marino suggested that the sample used in the carbon dating was from a corner of the cloth that had been mended using a technique known as invisible reweaving – an actual technique practiced by medieval tapestry restorers and practiced today by tailors to repair tears in expensive clothing.

At the behest of Benford and Marino, several textile experts examined documenting photographs of the radiocarbon samples and found what they believed was visual evidence of reweaving. Based on estimates from these photographs, and based on a historically-plausible date for reweaving, Ronald Hatfield of the radiocarbon dating firm Beta Analytic provided estimates that show that the cloth might be 2000 years old. (3)

Patches applied to the shroud following the 1532 fire were obvious; as noticeable as leather patches sewn to the elbows of an old sweater. Would repairs in 1531 (a plausible date from the historical records) or at any other time, have been so expertly done that that they would have gone unnoticed when the carbon 14 samples were cut from the cloth?

Rogers was skeptical. According to Ball, "Rogers thought that he would be able to 'disprove [the] theory in five minutes.'" (brackets are Ball's). *Inside the Vatican*, an independent journal on Vatican affairs, reported:

> Rogers, who usually viewed attempts to invalidate the 1988 study as 'ludicrous' . . . set out to show their [Benford and Marino] claim was wrong, but in the process, he discovered they were correct.

It was close examination of actual material from the shroud that caused Rogers to begin to change his mind. In 2002, Rogers, in collaboration with Anna Arnoldi of the University of Milan, wrote a paper arguing that the repair was a very real possibility. The material Rogers examined was from an area directly adjacent to the carbon 14 sample, an area known as the Raes corner. Rogers found a spliced thread. This was unexpected and inexplicable. During weaving of the shroud, when a new length of thread was introduced to the loom, the weavers had simply laid it in next to the previous length rather than splicing. Rogers and Arnoldi wrote:

> [The thread] shows distinct encrustation and color on one end, but the other end is nearly white . . . Fibers have popped out of the central part of the thread, and the fibers from the two ends point in opposite directions. This section of yarn is obviously an end-to-end splice of two different batches of yarn. No splices of this type were observed in the main part of the Shroud.

Rogers found alizarin, a dye produced from Madder root. The dye appeared to have been used to match new thread to older age-yellowed thread. In addition to the dye, Rogers found a gum substance (possibly gum Arabic) and alum, a common mordant used in medieval dying.

Several years earlier, a textile expert, Gilbert Raes (for whom the Raes corner is named), had been permitted to cut away a small fragment of the shroud. In it he found cotton fibers. Rogers confirmed the existence of embedded cotton fibers and noted that such cotton fibers are not found in other samples from anywhere else on the shroud. Cotton fibers were sometimes incorporated into linen threads during later medieval times, but not earlier, and

not even as early as the carbon 14 range of dates. This, along with the dyestuff, suggested some sort of alteration or disguised mending.

Rogers also noted that fibers in the Raes material contained less lignin than the rest of the shroud. Lignin is a chemical compound found in plant material including flax, the plant from which linen fibers are sourced. The most plausible explanation for this difference was that material in this area contained threads that had been bleached more efficiently. It was already known from the shroud's faint variegated appearance that the shroud's thread was probably bleached before weaving, probably with potash. This is not an exacting method and thus some hanks of yarn were whiter than others. As the cloth aged and naturally yellowed, the variegation became more pronounced, as can be seen in contrast-enhanced photographs. This form of ancient bleaching removed very little lignin.

Arguably, from a historical point of view (but not a scientific one) the linen cloth used for the shroud was not produced in medieval Europe. Even by the timeframe suggested by the radiocarbon dating, linen was "field bleached" after weaving. In field bleaching, the woven cloth was soaked in hot lye solution, washed, soaked in sour milk and washed again. Then it was spread out in fields in the sun. This process avoided the variegation produced by the more ancient methods of bleaching the thread before weaving. And it removed most of the lignin.

Lignin is significant not only because of the observed disparities but because it is the raw source for vanillin. Vanillin is produced from lignin by thermal decomposition. Rogers knew that if the shroud had been correctly carbon dated, the cloth should produce measurable amounts of the aromatic substance. Found in medieval linen, but not in much older cloth, vanillin diminishes and disappears with time. Rogers discovered that there was no detectable vanillin in the flax fibers of the main part of the shroud just as there is no vanillin in the linen wrapping from the Dead Sea Scrolls. There was, however, vanillin in the corner from which the carbon 14 samples were taken. He concluded that the main part of the shroud and the carbon 14 sample had a different age.

If the cloth had been manufactured in 1260, the earliest date suggested by carbon dating, it should have retained about 37% of its vanillin. Paraphrasing Rogers, Ball writes, "Let's call it somewhere around the middle of that range, which puts the age at about 2,000 years. Which can mean only one thing… (ellipsis are Ball's).

While this is not an accurate method for determining the age of linen because it depends on the average storage temperature over many centuries, it is useful as a sniff test for checking carbon 14 dating. Not only does this information verify that the carbon 14 sample is

chemically different from the rest of shroud, it demonstrates that the carbon 14 sample probably contained much newer material than the rest of the shroud.

The chemical differences and the vanillin analysis were significant. Ball, however, was not convinced that invisible reweaving was the underlying explanation. “Well, maybe,” he wrote, then added:

> There is no explanation, however, of how the ‘repaired’ threads used in the radiocarbon dating were woven into the old cloth so cunningly that the textile experts who selected the area for analysis failed to notice the substitution. This is by no means the end of the story.”

MUCH MORE TO THE STORY

Indeed, as Ball recognized, “This is by no means the end of the story.”

Rogers had been careful. Before submitting a paper for peer review, Rogers obtained some threads reserved from the middle of the radiocarbon sample. For the radiocarbon dating, one sample had been cut directly adjacent to the Raes corner. It was partially shared with the labs, one share by weight for each of the labs. About half of the full sample was reserved. In radiocarbon dating, whatever is being dated is incinerated until all that remains is carbon or carbon dioxide gas. It is therefore prudent to save some of the sample for further testing, should that become necessary. With these reserved threads, Rogers was able to confirm and expand his findings developed with material from the Raes corner.

Rogers also provided some material to John L. Brown, formerly Principal Research Scientist at the Georgia Tech Research Institute's Energy and Materials Sciences Laboratory at the Georgia Institute of Technology. Brown worked independently and with different methods, including a Scanning Electron Microscope. Rogers hoped for independent confirmation and he got it. Of one particular set of microscopic images, Brown wrote:

> This would appear to be obvious evidence of a medieval artisan’s attempt to dye a newly added repair region of fabric to match the aged appearance of the remainder of the Shroud.

As the *Associated Press*, the *BBC* and *The New York Times* reported on Rogers' *Thermochimica Acta* paper, some people wondered, just as Ball had, if it was possible that threads "were woven into the old cloth so cunningly that the textile experts who selected the area for analysis failed to notice the substitution." Others wondered if there was perhaps more to the story. Was this the whole story? How could such a mistake in radiocarbon dating happen? Was there something to learn from this?

About a year before Rogers' paper was published, in early 2004, the *Journal of Research of the National Institute of Standards and Technology* (U.S. Department of Commerce, NIST, U.S. Government Printing Office) published an important paper by Lloyd A. Currie. Currie, a highly regarded specialist in the field of radiocarbon dating and an NIST Fellow Emeritus, wrote a seminal retrospective on carbon 14 dating. Because the Shroud of Turin was such a famous test, Currie devoted much of his paper to it.

Like Rogers, Currie dismissed any argument that radiocarbon labs had done anything wrong in dating the Shroud of Turin. Currie also rejected, as Rogers also had done, the theories of scorching effects or contamination caused by a bioplastic polymer. Significantly, Currie acknowledged that disguised mending was a viable explanation. He cited the work of Rogers and Arnoldi. He found it credible.

Currie also raised an important issue of faulty procedures that could have prevented an error from invisible reweaving. According to Currie, the original sampling protocol required multiple samples from different locations on the cloth. (4) Archeologist William Meacham disagrees on historical detail but not scientific principle. In a recent email to about 100 shroud researchers, Meacham stated that the original protocol called for a single sample to be divided among seven labs. He wrote:

> Al Adler and I argued forcefully but unsuccessfully . . . for at least a second sample . . . the original protocol was seriously flawed, so it should not be described as some sort of properly designed scientific procedure that was put aside.

Regardless, had multiple samples been taken, the chemical differences between the sample area and the rest of the shroud would certainly have been obvious to the labs in 1988.

Rogers blamed church authorities in Turin for not following standard scientific protocol. In the interview with *Inside the Vatican* magazine, Rogers said:

> The sampling operation should have involved many persons from different fields before cutting anything . . . if you really want to get a radiocarbon data, take a lot of samples.

Ultraviolet and x-ray photographs taken in 1978, before the carbon 14 dating samples were removed, indicated that there were chemical differences between the sample area and surrounding areas of the cloth. Moreover, Alan Adler, Emeritus Professor of Chemistry at Western Connecticut State University, had found a significant quantity of aluminum in yarn segments from the general area of the sample. It is not found on other samples from elsewhere on the shroud. Alum, an aluminum compound, the common mordant used with Madder root dye, was certainly an explanation. Many wondered if the labs or church authorities had considered this evidence or were even aware of it when they changed (or adopted) the protocol. The article in *Inside the Vatican* addressed this:

> Asked whether he [Rogers] thought the authorities at Turin had been aware of such evidence as the 1978 photographs indicating that the corner of the Shroud from which they took the sample was unlike the rest of the cloth, Rogers responded that "it doesn't matter if they ignored it or were unaware of it. Part of science is to assemble all the pertinent data. They didn't even try."

RED FLAGS

There were other clues, as well. All of them were warning signs that something might be wrong with the carbon 14 samples:

- Giovanni Riggi, the person who actually cut the carbon 14 sample from the Shroud stated, "I was authorized to cut approximately 8 square centimetres of cloth from the Shroud…This was then reduced to about 7 cm because *fibres of other origins* had become mixed up with the original fabric …" (emphasis mine)

- Giorgio Tessiore, who documented the sampling, wrote: "…1 cm of the new sample had to be discarded because of the *presence of different color threads*." (emphasis mine)

- Edward (Teddy) Hall, head of the Oxford radiocarbon dating laboratory, had noticed fibers that looked out of place. A laboratory in Derbyshire concluded that the rogue fibers were cotton of "a fine, dark yellow strand." Derbyshire's Peter South wrote: "It may have been used for repairs at some time in the past…"

- Gilbert Raes, when later he examined some of the carbon 14 samples, noticed that cotton fibers were contained inside the threads, which could help to explain differences in fiber diameter. This may also explain why the carbon 14 samples apparently weighed much more than was as expected.

- Alan Adler at Western Connecticut State University found large amounts of aluminum in yarn segments from the radiocarbon sample, up to 2%, by energy-dispersive x-ray analysis. Why aluminum? That was an important question because it is not found elsewhere on the Shroud.

- The radiocarbon lab at the University of Arizona conducted eight tests. But there was a wide variance in the computed dates and so the team in Arizona combined results to produce four results thus eliminating the more outlying dates (reportedly they did so at the request of the British Museum, which was overseeing the tests). Even then, according to Remi Van Haelst, a retired industrial chemist in Belgium, the results failed to meet minimum statistical standards (chi-squared tests). Why the wide variance in the dates? Was it because of testing errors? Or was it because the sample was not sufficiently homogeneous? The latter seems very likely now, and the statistical anomaly indicates something very suspicious about the samples.

- Bryan Walsh, a statistician, examined Van Haelst's analysis and further studied the measurements. He concluded that the divided samples used in multiple tests contained different levels of the C14 isotope. The overall cut sample was non-homogeneous and thus of questionable validity. Walsh found a significant relationship between the measured age of various sub-samples and their distance from the edge of the cloth. Though Walsh did not suggest invisible reweaving, it is consistent with his findings.

FACTS VS EXPLANATIONS

It is important to distinguish between observed facts and likely explanations. The sample used for the radiocarbon dating is chemically unlike the shroud. That is observed fact. It invalidates the sample and thus the conclusion of the tests. The spliced thread and the dyestuff suggest disguised mending. Disguised mending caused consternation among some. Ball wondered why it was not seen. He is not alone.

Archeologist William Meacham was skeptical when Benford and Marino first proposed mending; long before Rogers examined the material. He had previously discussed this possibility with the archeological scientist Stuart Fleming who said that it was within the realm of possibility. But Meacham was not yet convinced. He challenged Benford and Marino, "to find at least one textile historian who could answer these questions [about it escaping notice] in support of their thesis."

They did so. According to Benford and Marino, Dr. Thomas Campbell, Associate Curator, European Sculpture and Decorative Arts, The Metropolitan Museum of Arts, described the sixteenth century French weavers as 'magicians.' It was very difficult to identify their repairs. (2002)

Mechthild Flury-Lemberg, who directed a controversial restoration of the shroud in 2002, was another holdout. During the restoration she had not seen any evidence of repairs and stated that "reweaving in the literal sense does not exist" and that any such reweaving would be visible on the back side of the cloth.

But the invisible reweaving art did exist. It existed in medieval Europe just as it does today. In a peer-reviewed paper presented at the Third International Dallas Conference on the Shroud of Turin in September, 2005, Benford and Marino explain why the repairs may not have been noticed. And they correct Flury-Lemberg's statement that any such repair would have been visible on the back side of the cloth.

Michael Ehrlich, the president and owner of a Chicago-based company called "Without A Trace" provides invisible mending services for clients throughout the United States. He explains that there are two types of reweaving: inweaving, which is noticeable from the back side of the cloth (as Flury-Lemberg stated) and a technique called French weaving. French weaving was practiced in Europe during the time when it is likely that the cloth would have been repaired. Benford and Marino explain:

> French Weaving, now only done on small imperfections due to its extensive cost and time, results in both front and back side 'invisibility.' According to Mr. Ehrlich, French Weaving involves a tedious thread-by-thread restoration that is undetectable. Mr. Ehrlich further stated that if the 16th Century owners of the Shroud had enough material resources, weeks of time at their disposal, and expert weavers available to them, then they would have, most definitely, used the French Weave for repairs . . . the House of Savoy, which was the ruling family in parts of

> France and Italy, owned the Shroud in the 16th century, and possessed all of these assets.

LOS ALAMOS LABORATORY STUDY IN 2008

In a presentation The Ohio State University's Blackwell Center, Los Alamos National Laboratory (LANL) chemist, Robert Villarreal, disclosed new findings showing that the sample of material used in 1988 to Carbon dating could not have been from the original linen cloth because it was cotton. According to Villarreal, who lead the LANL team working on the project, thread samples they examined from directly adjacent to the sampling area were "definitely not linen" and, instead, matched cotton. Villarreal pointed out:

> the [1988] age-dating process failed to recognize one of the first rules of analytical chemistry, that any sample taken for characterization of an area or population must necessarily be representative of the whole. The part must be representative of the whole. Our analyses of the three thread samples taken from the Raes and C-14 sampling corner showed that this was not the case.

Villarreal also revealed that, during testing, one of the threads came apart in the middle forming two separate pieces. A surface resin, that may have been holding the two pieces together, fell off and was analyzed. Surprisingly, the two ends of the thread had different chemical compositions, lending credence to Rogers' finding in *Thermochimica Acta* by the late Raymond Rogers.

After conducting analysis at high vacuum with the ToF-SIMS, the "spliced thread" broke into three distinct pieces; a fuzzy end (Region 1), a tight woven end (Region 2), and a micro-sized circular cocoon-shaped brown crust that seemed to be connecting the two end pieces. The ToF-SIMS results were the first to show that the spectra from the two ends were similar to cotton rather than linen (flax) and the Spectroscopist recommended that the next analysis should be with the FTIR instrument. After several scans of individual fibers or strands, the FTIR data showed that the two ends (Region 1 and 2) were definitely cotton and not linen (flax). The crust appeared to be an organic-based resin, perhaps a terpene species, with cotton as a main sub-component. After showing the FTIR data to Barrie Schwortz and Sue Benford, they were quite surprised at the results and decided to send me two other pieces of thread (No. 7 and 14) that were from the same sampling area and that had been in John Brown's Lab in Marrietta, Georgia.

The results of the FTIR analysis on all three threads taken from the Raes sampling area (adjacent to the C-14 sampling corner) led to identification of the fibers as cotton and definitely not linen (flax). Note, that all age dating analyses were conducted on samples taken from this same area. Apparently, the age-dating process failed to recognize one of the first rules of analytical chemistry that any sample taken for characterization of an area or population must necessarily be representative of the whole. The part must be representative of the whole. Our analyses of the three thread samples taken from the Raes

and C-14 sampling corner showed that this was not the case. What was true for the part was most certainly not true for the whole. This finding is supported by the spectroscopic data provided in this presentation.

The recommendations that stem from the above analytical study is that a new age dating should be conducted but assuring that the sample analyzed represents the original main shroud image area, i.e. the fibers must be linen (flax) and not cotton or some other material. It is only then that the age dating will be scientifically correct.

OTHER THEORIES

An article in Chemistry Today (August 2008) summarizes nicely:

> Since the dating, many hypotheses have been proffered attempting to explain the C-14 results, which appear contradictory to a plethora of data pointing to a more ancient origin. An acceptable hypothesis of why the Shroud dated between AD 1260-1390 must satisfactorily explain the precise, statistically-determined angular skewing of the dates corresponding with the individual laboratories, with reference to the location of the sub samples received. The hypotheses of generalized ionizing radiation, thermal effects, environmental carbon monoxide enrichment and bio plastic coating are incapable of meeting this latter requirement, as is the premise that the cloth itself, is, in toto, medieval (2).

ANSWERING THE STUDENTS' QUESTIONS

One day, I received an email from a high school student in Alaska. Her chemistry teacher handed out a list entitled, "Carbon 14 Dating Successes." The topmost item on the list read, "Shroud of Turin – Proven Fake."

"I asked my teacher about it but was ridiculed for not being scientific," she wrote. Later, during a true or false examination, the student had to acquiesce to the "truth" that the shroud was fake or be marked down. She objected. She brought in an article from Wikipedia and another article obtained from the internet (she was writing to me in search of more articles). Her teacher told her, in front of the entire class, that she could believe anything she wants about her "religion," but when it comes to science the shroud is a fake, and that is a "scientific fact."

Such a response from a science teacher is neither good teaching nor good science. The honest answer is that we *probably* do not know the provenance of the shroud just as we do not know how the image was formed.

Another student wrote to me, "Let's have a do over." It is difficult to find a serious shroud researcher who would not agree. But what would have to happen before new radiocarbon dating test could take place?

NOTES

Images: Numerous images in support of this article may be found at http://www.innoval.com/C14

1. Some researchers point to an avalanche of other data that suggests authenticity despite whatever the radiocarbon dating results suggest. Some of this data, such as the chemistry of the bloodstains is well documented in peer-reviewed scientific journals. Some of it, such as geographic specific pollen identification, needs further study. Some of it is based on historical documentation and it should be considered. But it is the unexplained image that universally prompts us to wonder about the provenance of the shroud. One microscopist, Walter McCrone, claimed that he found paint particles in samples taken from the shroud. But every other scientist who has physically examined the shroud or the samples disagrees. The spectral analysis is quite conclusive.

2. There were other hypotheses as well. For instance it has been suggested that the "resurrection of Jesus" changed the radiocarbon content. Such an idea, of course, cannot be tested. And, as can be expected, conspiracy theories will attach themselves to controversial scientific findings. One is that the samples were secretly switched and any number of reasons why this might have been done have been advanced.

3. For clarity, Benford and Marino are quoted here: "According to Ronald Hatfield, a scientist at Beta Analytic, the world's largest radiocarbon dating service, a merging of threads from AD 1500 into a 2,000 year old piece of linen would augment the C-14 content, such that a 60/40 ratio of new material to old, determined by mass, would result in a C-14 age of approximately AD 1210 (Beta Analytic Laboratories, 2000). This correlates very closely with the Oxford mean date of AD 1200 as reported in Nature (Damon, 1989:613) and with the observed ratio of original versus medieval material in the C-14 sample."

4. According to Currie: “The critical, non-AMS issue relates to sample validity. The originally agreed upon sampling protocol was to have involved seven laboratories, two measurement techniques (decay and atom [AMS] counting), and multiple samples representing different regions of the cloth. Shortly before the event, however, the scheme was changed to restrict the number of laboratories (all AMS) and the number of samples to three, all taken from the same location. The sampling location, near a corner of the Shroud, and near an area damaged by the fire of 1532 AD, is considered an unfortunate choice, because of the possibility of exogenous carbon from the fire, repairs, and organic contamination from handling through the ages.” [cites Gove]

But, according to Meacham: “This account is incorrect. The original protocol called for ONE sample to be cut from the Shroud and divided into seven segments to be distributed to the seven labs. . . To me, as an archaeologist with 17 years’ experience in the application of C-14 dating to field contexts, this proposal seemed absurd. One should seize the opportunity to date samples from different parts of the cloth, avoiding a possibly anomalous (e.g. starched) area. This is the major scientific question now relevant. The dating of the Shroud is not, after all, a laboratory inter-comparison experiment. Three dates from reputable labs, hopefully on samples from three different sites on the relic, should give a good indication of the radiocarbon age of the cloth, and whether or not random contamination or other problems exist which require sophisticated testing techniques."

5. In a private email, Van Haelst commented for this article: “Arizona did not select four dates. In fact they combined 4 times TWO dates, obtained the same day, using the same standards and blanks. This gives (see chart):

Sample Combinations and Resulting Errors			
$606/41^2$	$574/45^2$		
$\frac{}{1/41^2} + \frac{}{1/45^2}$	= 591	$(1/(1/71^2 + 1/45^2))^{0.5}$ = 30	
$753/51^2$	$632/49^2$		
$\frac{}{1/51^2} + \frac{}{1/49^2}$	= 690	$(1/((1/51^2 + 7/49^2))^{0.5}$ = 35	

$\frac{540/57^2}{1/57^2} + \frac{676/59^2}{1/59^2} = 606$ $(1/(1/57^2 + 1/59))^{0.5} = 41$
$\frac{701/47^2}{1/47^2} + \frac{701/47^2}{1/47^2} = 701$ $(1/(1/47^2 + 1/47^2))^{0.5} = 33$

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